in many combinations other than the specific examples described above, under the scope of the following claims.

We claim:

1. Process for separating first and second components of a feed gas mixture, the first component being more readily adsorbed under increase of pressure relative to the second component which is less readily adsorbed under increase of pressure over an adsorbent material, such that a gas mixture of the first and second components contacting the adsorbent material is relatively enriched in the first component at a lower pressure and is relatively enriched in the second component at a higher pressure when the pressure is cycled between the lower and higher pressures at a cyclic frequency of the process defining a cycle period; providing for the process a number "N" of substantially similar adsorbent beds of the adsorbent material, with said adsorbent beds having first and second ends; and further providing for the process a first rotary distributor valve connected in parallel to the first ends of the adsorbent beds and a second rotary distributor valve connected in parallel to the second ends of the adsorbent beds, with flow controls cooperating with the first and second distributor valves; introducing the feed gas mixture at substantially the higher pressure to the first distributor valve; and rotating the first and second distributor valves so as to perform in each adsorbent bed the sequentially repeated steps within the cycle period of:

(A) supplying a flow of the feed gas mixture at the higher pressure through the first distributor valve to the first end of the adsorbent bed during a feed time interval, withdrawing gas enriched in the second component from the second end of the adsorbent bed, and delivering a portion of the gas enriched in the second component as a light product gas,

(B) withdrawing a flow of gas enriched in the second component as light reflux gas from the second end of the adsorbent bed through the second distributor valve, so as to depressurize the adsorbent bed from the higher pressure toward an equalization pressure less than the higher pressure, while controlling the flow so that the pressure in the bed approaches the equalization pressure within an equalization time interval,

(C) withdrawing a flow of light reflux gas enriched in the second component from the second end of the adsorbent bed through the second distributor valve, so as to depressurize the adsorbent bed from approximately the equalization pressure to an intermediate pressure less than the equalization pressure and greater than the lower pressure, while controlling the flow so that the pressure in the bed reaches approximately the intermediate pressure within a cocurrent blowdown time interval,

(D) withdrawing a flow of gas enriched in the first component from the first end of the adsorbent bed through the first distributor valve, so as to depressurize the adsorbent bed from approximately the intermediate pressure to approach the lower pressure, while controlling the flow so that the pressure in the bed approaches the lower pressure within a countercurrent blowdown time interval,

(E) returning a flow of light reflux gas enriched in the second component from the second distributor valve to the second end of the adsorbent bed at substantially the lower pressure, while withdrawing gas enriched in the first component from the first end of the adsorbent bed and through the first distributor valve over a purge time interval, said flow of gas enriched in the second component from the second distributor valve being withdrawn from another of the adsorbent beds which is undergoing cocurrent blowdown step (C) of the process,

(F) returning a flow of light reflux gas enriched in the second component from the second distributor valve to the bed, so as to repressurize the adsorbent bed from approximately the lower pressure to approach the equalization pressure, while controlling the flow so that the pressure in the bed approaches the equalization pressure within an equalization time interval, said flow of gas enriched in the second component from the second distributor valve being withdrawn from another of the adsorbent beds which is undergoing equalization step (B) of the process,

(G) admitting gas to the adsorbent bed, so as to further repressurize the adsorbent bed from the equalization pressure toward the higher pressure, while controlling the flow so that the pressure in the bed approaches the higher pressure within a repressurization time interval,

(H) cyclically repeating steps (A) to (G).

2. The process of claim 1, further varying cycle frequency so as to achieve desired purity, recovery and flow rate of the light product gas.

3. The process of claim 1, in step (G) returning a flow of light reflux gas enriched in the second component from the second distributor valve to the bed, so as to repressurize the adsorbent bed to approach the higher pressure, while controlling the flow so that the pressure in the bed approaches the higher pressure within a repressurization time interval, the flow of gas enriched in the second component from the second distributor valve being withdrawn from another of the adsorbent beds which is undergoing feed step (A) of the process.

4. The process of claim 1, in step (G) admitting feed gas from the first distributor valve to the bed, so as to repressurize the adsorbent bed to approach the higher pressure, while controlling the flow so that the pressure in the bed approaches the higher pressure within a repressurization time interval.

5. The process of claim 1, supplying the feed gas mixture during the initial part of step (A) to the first end of the adsorbent bed, and then supplying a second feed gas with a greater concentration of the first component during the later part of step (A) to the first end of the adsorbent bed.

6. The process of claim 5, recompressing a portion of the gas enriched in the first component withdrawn from the first end of an adsorbent bed during step (D) or preferably (E) to substantially the higher pressure, and supplying this portion of the gas enriched in the first component as the second feed gas through the first distributor valve to the first end of the adsorbent bed in the latter part of the feed time interval in step (A).

7. The process of claim 6, providing a feed selector valve to alternatingly direct the feed gas mixture or the heavy reflux gas through the first distributor valve to the first end of the adsorbent bed, and switching the feed selector valve at a frequency "N" times the cycle frequency.

8. The process of claim 1, exchanging light reflux gas enriched in the second component between a bed undergoing step (B) and another bed undergoing step (F) directly through the second distributor valve in substantially identical equalization time intervals for those steps (B) and (F).

9. The process of claim 8, in which the cycle period is approximately the sum of the feed time interval, twice the equalization time interval, the cocurrent blowdown time interval, the purge time interval, and the repressurization time interval.

10. The process of claim 1, further providing adjustable orifices interposed between the second end of each adsorbent bed and the second distributor valve as flow controls cooperating with the second distributor valve, one adjustable orifice being provided for each bed and the orifices being adjusted simultaneously so as to have substantially identical settings at any time, and adjusting the orifices so as to control the flow at the second ends of the adsorbent beds in steps (B), (C), (E), (F) and (G).

11. The process of claim 10, further providing a product delivery check valve for each adsorbent bed communicating from the second end of that adsorbent bed to a light product manifold, and delivering the light product through the product delivery check valves.

12. The process of claim 10, in which the time intervals of steps (B), (C) and (F) are substantially equal, so that the intermediate pressure remains substantially constant as the orifices are adjusted.

13. The process of claim 10, in which the orifices are adjusted by switching between discrete settings.

14. The process of claim 1, further delivering the light product gas through the second distributor valve.

15. The process of claim 1, further providing an adjustable orifice in the second distributor valve as a flow control cooperating with the second distributor valve, and adjusting the orifice so as to control the flow in step (C).

16. The process of claim 1, further providing adjustable orifices in the second distributor valve as flow controls cooperating with the second distributor valve, and adjusting the orifices so as to control the flow at the second ends of the adsorbent beds in steps (B), (C), (E), (F) and (G).

17. The process of claim 1, further providing a flow control cooperating with the first distributor valve to control the flow in step (D) so as to establish the intermediate pressure relative to the higher and lower pressures, such that the ratio of the difference between the intermediate pressure and the lower pressure to the difference between the higher pressure and the lower pressure is in the range of approximately 0.15 to 0.25.

18. The process of claim 1, further controlling the flow in step (A) by establishing the volumetric flow of the feed gas mixture at the higher pressure.

19. The process of claim 1, further controlling the flow in step (A) by regulating the pressure at which the product gas is withdrawn.

20. The process of claim 1, further controlling the flow in each step so as to avoid damaging the adsorbent by transient high flow velocity in the adsorbent bed.

21. The process of claim 1, further controlling the flow velocities in steps (B), (C), (D), (F) and (G) so that the ratio of the peak flow velocity to the average flow velocity in those steps will not exceed approximately 2:1.

22. Apparatus for separating first and second components of a feed gas mixture, the first component being more readily adsorbed under increase of pressure relative to the second component which is less readily adsorbed under increase of pressure over an adsorbent material, such that a gas mixture of the first and second components contacting the adsorbent material is relatively enriched in the first component at a lower pressure and is relatively enriched in the second component at a higher pressure when the pressure is cycled between the lower and higher pressures at a cyclic frequency of the process defining a cycle period, the apparatus including

(a) a number "N" of substantially similar adsorbent beds of the adsorbent material, with said adsorbent beds having first and second ends defining a flow path through the adsorbent material;

(b) light product delivery means to deliver a light product flow of gas enriched in the second component from the second ends of the adsorbent beds;

(c) a first rotary distributor valve connected in parallel to the first ends of the adsorbent beds; the first distributor valve having a stator and a rotor rotatable about an axis; the stator and rotor comprising a pair of relatively rotating valve elements, the valve elements being engaged in fluid sealing sliding contact in a valve surface, the valve surface being a surface of revolution coaxial to the axis, each of the valve elements having a plurality of ports to the valve surface and in sequential sliding registration with the ports in the valve surface of the other valve element through the relative rotation of the valve elements; one of the valve elements being a first bed port element having N first bed ports each communicating to the first end of one of the N adsorbent beds; and the other valve element being a first function port element having a plurality of first function ports including a feed port, a countercurrent blowdown port and a purge exhaust port; with the bed ports spaced apart by equal angular separation between adjacent ports; and with the first function ports and first bed ports at the same radial and axial position on the valve surface so that each first function port is opened in sequence to each of the N first bed ports by relative rotation of the valve elements;

(d) a second rotary distributor valve connected in parallel to the second ends of the adsorbent beds and cooperating with the first distributor valve; the second distributor valve having a stator and a rotor rotatable about an axis; the stator and rotor comprising a pair of relatively rotating valve elements, the valve elements being engaged in fluid sealing sliding contact in a valve surface, the valve surface being a surface of revolution coaxial to the axis, each of the valve elements having a plurality of ports to the valve surface and in sequential sliding registration with the ports in the valve surface of the other valve element through the relative rotation of the valve elements; one of the valve elements being a second bed port element having N second bed ports each communicating to the second end of one of the N adsorbent beds; and the other valve element being a second function port element having a plurality of second function ports including a plurality of light reflux withdrawal ports and light reflux return ports, with each light reflux return port communicating through the second function element to a light reflux withdrawal port; with the bed ports spaced apart by equal angular separation between adjacent ports; and with the function ports and bed ports at the same radial and axial position on the valve surface so that each function port is opened in sequence to each of the N bed ports by relative rotation of the valve elements;

(e) drive means to establish rotation of the rotors, and hence relative rotation of the bed port elements and the function port elements of the first and second distributor valves, with a phase relation between the rotation of the rotors and angular spacing of the function ports of the first and second distributor valves so as to establish for each adsorbent bed communicating to corresponding first and second bed ports the following sequential and cyclically repeated steps at a cycle frequency for those bed ports:

(i) the first bed port is open to the feed port, while light product gas is delivered by the light product delivery means,

(ii) the second bed port is open to a light reflux withdrawal port,

(iii) the first bed port is open to the countercurrent blowdown port,

(iv) the first bed port is open to the purge exhaust port, while the second bed port is open to a light reflux return port;

(f) countercurrent blowdown flow control means cooperating with the first distributor valve;

(g) light reflux flow control means cooperating with the second distributor valve;

(h) feed supply means to introduce the feed gas mixture to the feed port of the first distributor valve at substantially the higher pressure; and

(i) exhaust means to remove gas enriched in the first component from the purge exhaust port of the first distributor valve.

23. The apparatus of claim 22, in which the second function ports of the second distributor valve include light reflux withdrawal ports to withdraw light reflux gas enriched in the second component from beds undergoing feed, equalization depressurization and cocurrent blowdown steps; light reflux return ports to supply gas enriched in the second component to beds undergoing purge, equalization pressurization and repressurization steps; and each light reflux withdrawal port communicates to a light reflux return port through an orifice; so as to establish by rotation of the distributor valve rotors the following sequential and cyclically repeated steps for the adsorbent bed of:

(A) the first bed port is open to the feed port, while the second bed port is open to a light reflux withdrawal port communicating through an orifice to a light reflux return port open to repressurize another bed undergoing step (F) below, and light product gas is delivered from the second end of the adsorbent bed by a light product delivery valve;

(B) the second bed port is open for pressure equalization to a light reflux withdrawal port communicating through an orifice to a light reflux port open to another bed undergoing step (F) below, so as to equalize the pressures of the beds;

(C) the second bed port is open for cocurrent blowdown to a light reflux withdrawal port communicating through an orifice to a light reflux port open for purging to another bed undergoing step (E) below;

(D) the first bed port is open to the countercurrent blowdown port, so as to depressurize the bed to the lower pressure;

(E) the first bed port is open to the purge exhaust port, while the second bed port is open to a light reflux return port so as to receive light reflux gas from another bed undergoing step (C) above;

(F) the second bed port is open to a light reflux return port so as to receive light reflux gas from another bed undergoing step (B) above for pressure equalization; and

(G) the second bed port is open to a light reflux return port so as to receive light reflux gas from another bed undergoing step (A) above for repressurization.

24. The apparatus of claim 23, in which the first bed port is opened to the feed port before light product gas is delivered from the second end of the adsorbent bed by the light product delivery valve, so that repressurization of the adsorbent bed is achieved at least in part by'feed gas.

25. The apparatus of claim 23, in which each light reflux withdrawal port communicates to a light reflux return port through an orifice which is an adjustable orifice, provided as light reflux flow control means.

26. The apparatus of claim 23, in which the first bed port element is the stator, and the first function port element is the rotor, of the first distributor valve; and the second bed port element is the stator, and the second function port element is the rotor, of the second distributor valve.

27. The apparatus of claim 26, in which each light reflux withdrawal port communicates to a light reflux return port through an orifice which is an adjustable orifice within the rotor, provided as light reflux flow control means.

28. The apparatus of claim 26, with actuator means to control the adjustable orifice from outside the rotor while the rotor is revolving.

29. The apparatus of claim 28, in which the adjustable orifice is provided as a throttle valve within the rotor, and the actuator means is coupled to the throttle valve through a mechanical linkage.

30. The apparatus of claim 26, in which each light reflux withdrawal port communicates to a light reflux return port through an adjustable orifice which is a throttle valve external to the rotor, with transfer chambers having rotary seals providing fluid communication between the throttle valve and the light reflux withdrawal port, and between the throttle valve and the light reflux return port.

31. The apparatus of claim 26, in which the light reflux control means includes an adjustable orifice or throttle valve interposed between the second end of each adsorbent bed and the second distributor valve, and means to adjust the orifices or throttle valves simultaneously such that each of the adjustable orifices will have substantially identical settings at each time.

32. The apparatus of claim 31, in which each of the adjustable orifices is provided by at least two fixed orifices in parallel, with one of the fixed orifices always open to flow, and another orifice being opened or closed to flow by a selector valve so as to establish respectively less restrictive and more restrictive discrete settings of the adjustable orifice.

33. The apparatus of claim 31, in which the light product delivery means for each adsorbent bed is provided as a check valve enabling flow from the second end of that adsorbent bed to a product delivery manifold.

34. The apparatus of claim 31, in which the light product delivery means is the second distributor valve, provided with a light product delivery port; and a check valve is provided in parallel with each adjustable orifice or throttle valve so as to permit unrestricted flow from the second end of each bed to the second distributor valve.

35. The apparatus of claim 22, with the drive means being a variable speed drive controlled by a cycle frequency controller.

36. The apparatus of claim 22, with the drive means including angular velocity variation means to vary the angular velocity of the rotor of the first distributor valve at a multiple "N" times the cycle frequency, so as to extend the time interval during which a function port is substantially fully open to each bed port, and to reduce the time interval during which that function port is substantially closed to any bed port, while maintaining the minimum angular velocity of the rotor during the cycle to be greater than zero.

37. The apparatus of claim 36, in which the angular velocity variation means is provided as a pair of noncircular gears in the drive train to the first distributor valve.

38. The apparatus of claim 22, in which a function port is shaped so as to provide a gradually opening orifice so as to impose relatively intensive throttling at the beginning of a blowdown, pressurization or equalization step.

39. The apparatus of claim **22**, in which the valve surface of a distributor valve is a flat disc normal to the axis of that valve, and with loading means to establish fluid sealing sliding contact between the stator and rotor of that distributor valve.

40. The apparatus of claim **39**, in which the loading means is in part provided by compression springs.

41. The apparatus of claim **39**, in which the loading means includes a plurality of axially aligned loading pistons disposed in a coaxial annulus within the valve rotor at substantially the radius of the function ports, with each piston communicating to the local gas pressure at its axially projected position in the valve surface, and the pistons reacting against a rotating thrust plate so as to achieve approximate radial balance.

42. The apparatus of claim **39**, in which the loading means to establish fluid sealing contact between the rotor and stator is provided by axially aligned fluid transfer sleeves for each bed port of the stator and providing sealed fluid communication to the corresponding adsorbent bed of each bed port, with the fluid transfer sleeves having enough axially projected area so as to thrust the stator against the rotor in sealing contact, with optional assistance of compression springs.

43. The apparatus of claim **42**, in which a clearance space between stator and the fluid transfer sleeves may be used as a fluid flow passage to achieve enhanced convective cooling of the valve.

44. The apparatus of claim **39**, in which the loading means to establish fluid sealing contact between the rotor and stator is provided by a thrust slipper reacting against a stationary thrust plate and engaged by axially compliant sealing means to the valve rotor so as to define a chamber pressurized by feed fluid to thrust the rotor against the valve sealing surface.

45. The apparatus of claim **44**, in which the thrust slipper provides fluid transfer means to convey feed fluid from a stationary housing to the rotor.

46. The apparatus of claim **44**, in which the thrust slipper is eccentrically positioned and radially offset from the axis of said rotor toward the high pressure feed port and away from the low pressure exhaust port, so as to balance approximately the pressure distribution in the valve sealing surface.

* * * * *